CPST GTA Overview

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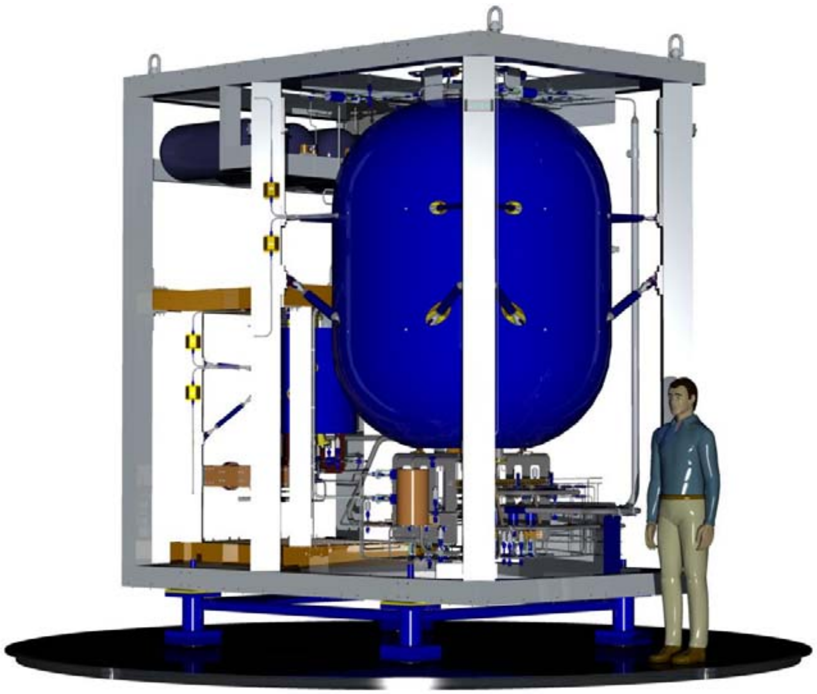
Why GTA – A Historical Perspective

- GTA was proposed in June 2011 and given ATP August 2011
- Proposed as a lean engineering effort to help address the following gaps:
  - Need for integrated flight-like CFS Storage Tank Assembly
    - Manufacturing flight weight tank
    - Integration concerns with hardware internal and external on flight weight tank.
    - Flight similar LADs integrated within assembly
  - Need for understanding of performance interactions
    - Interactions between thermal system, TVS, LADs, instrumentation, and quantity gauging within Storage Tank Assembly
    - Interactions between Storage Tank assembly, transfer system, and transfer tank assembly for heat leaks / propellant losses.
    - Orientation / fluid location effect on acquisition and pressurization performance
  - Need for data from an integrated flight scale system to anchor mathematical models
    - Overall heat loads, transfer performance, pressurization performance, etc.
  - Need for early software sequence development / evaluation for autonomous flight operations
  - Need for flight system development / pathfinder design /build / test activity feeding into critical design phase.

Ground Test Article (GTA) Overview

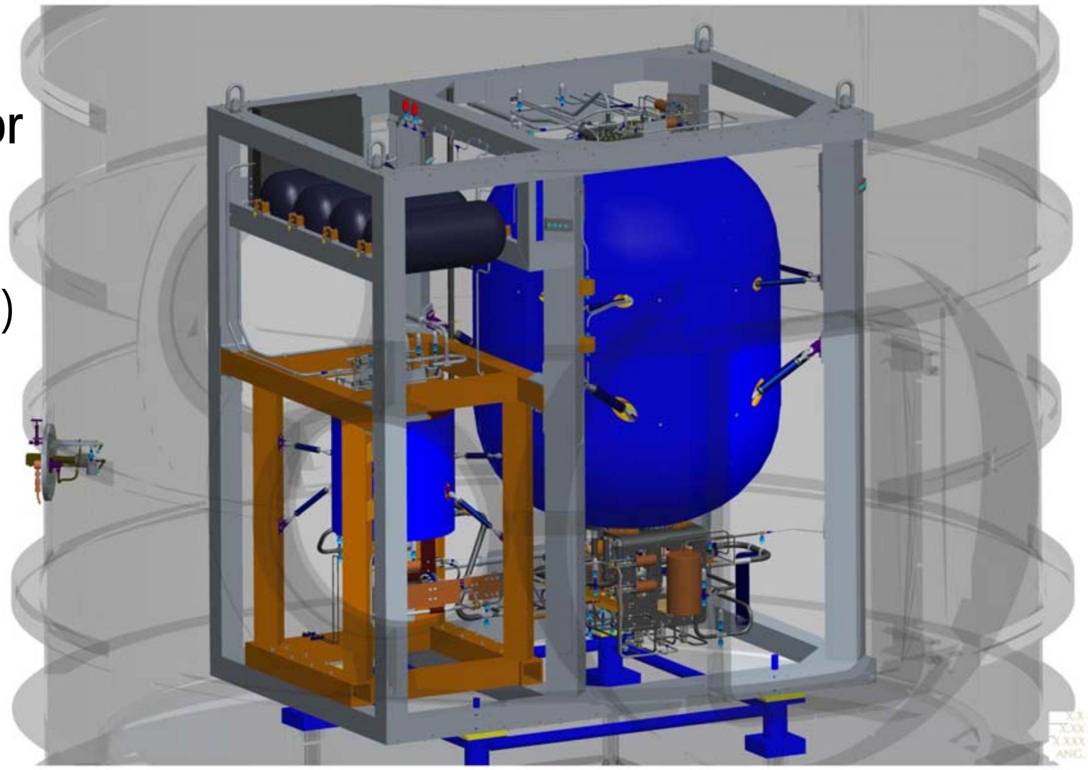
- GTA Description
  - A technology development version of the CPST CFM Payload with all CPST functionality (Pre-Phase A)
  - GTA consists of flight-like:
    - Storage and Transfer Tanks
    - LADs (channel and vane)
    - Passive Thermal features and interfaces
    - Transfer and Pressurization Systems
    - Instrumentation
  - Designed to perform integrated passive and active thermal, storage and transfer during LN2 functional testing and LH2 performance testing in vacuum environment



- GTA Scope:
  - Demonstrate thermal vacuum performance for a simulated mission environment
  - Perform Integrated System Performance for all modes of operation to allow for correlation of math models to help anchor Flight Payload design
  - Mature and evaluate flight-like design interface details for manufacturability
  - Demonstrate flight tank prototype manufacturing and streamlined engineering
  - Demonstrate flight-like LAD manufacture and integration
  - Overall assembly and integration

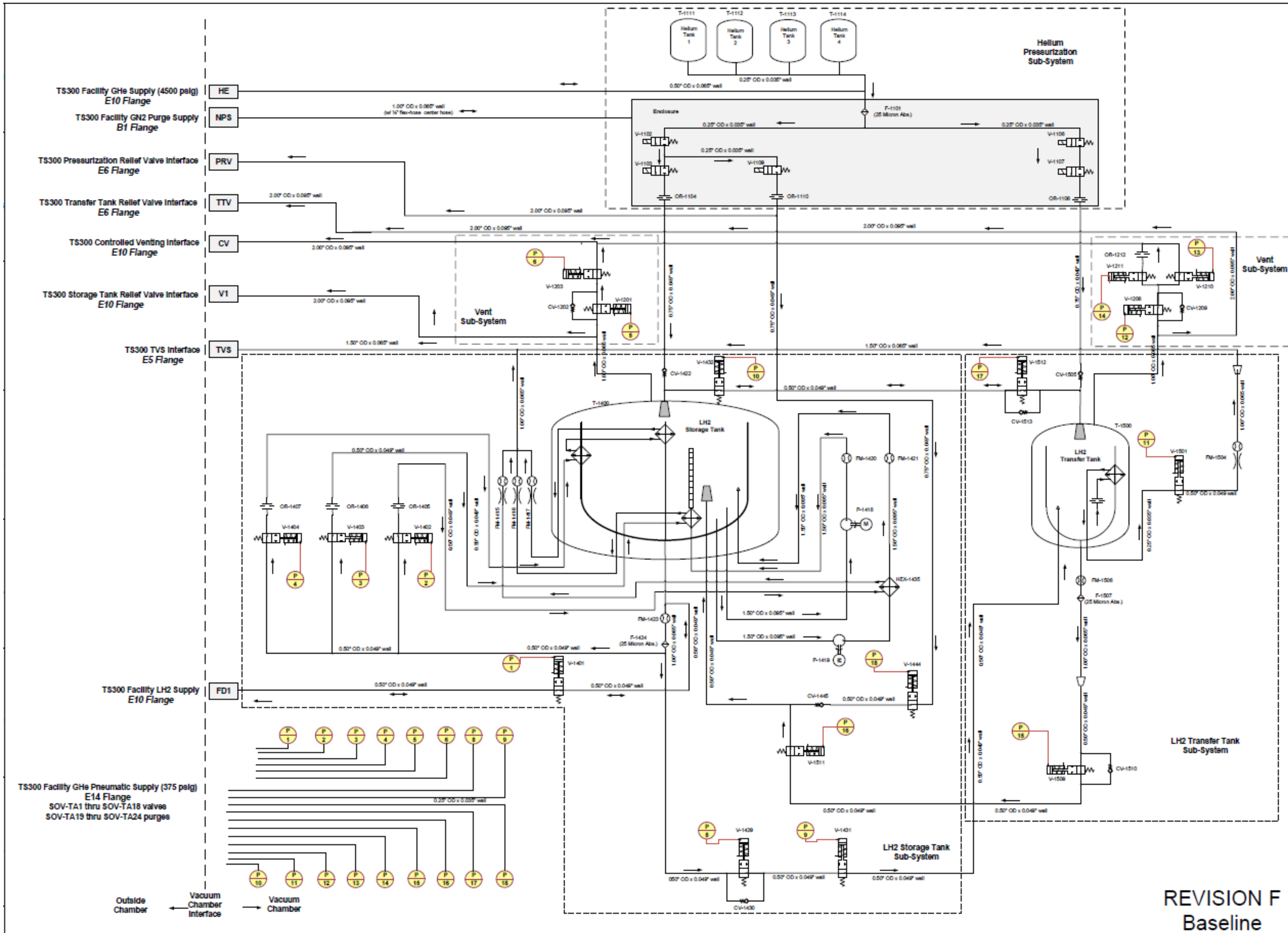
GTA Description

- GTA Side-by-Side Configuration:
  - Accessibility to Components
- Government Pre-Phase A basis for Design
  - LH2 Only
  - Storage Tank LH2 Capacity (260kg)
  - ANTARES Launch Vehicle
  - Technology Demonstration Capabilities
- Major subsystems:
  - Pressurization System*
  - Storage Tank Assembly*
  - Transfer Tank Assembly*
  - Transfer System*
- Designed to be tested at MSFC TS300



*Subassemblies include all of the passive thermal, fluid and structural features and interfaces.

GTA Schematic



REVISION F
Baseline
Last Updated: 2013-04-30

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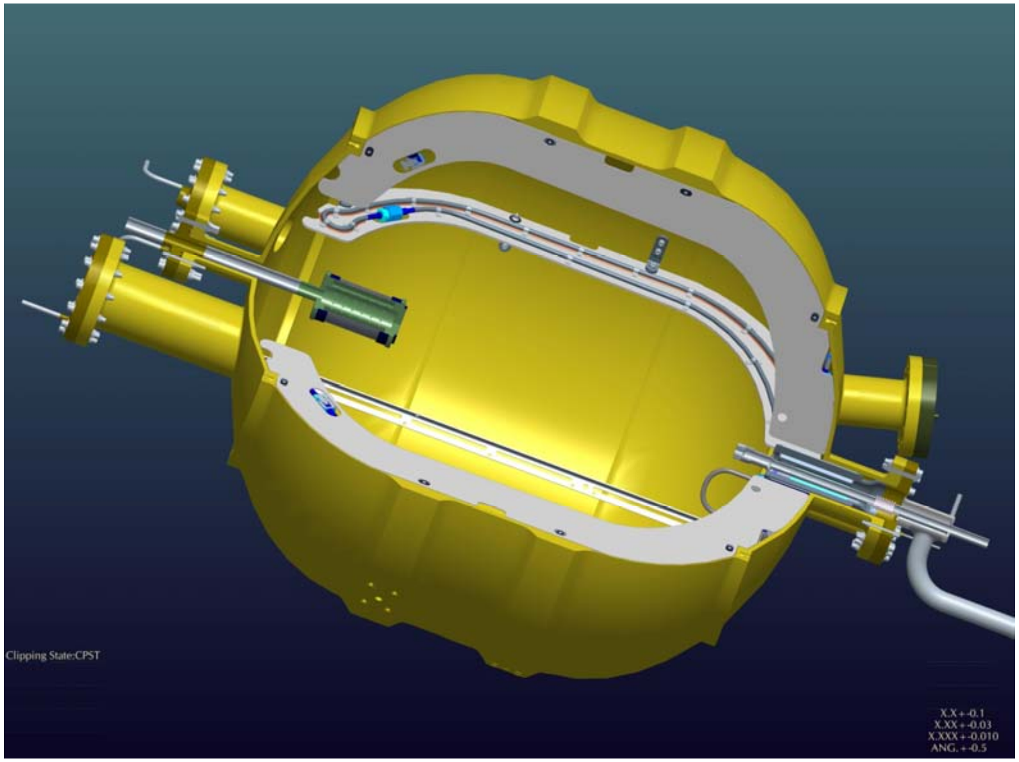
Flight Representative Capabilities to be Demonstrated on GTA

- LH2 Cryogenic Fluid Storage
  - Low Conductivity Structures
    - Storage and Transfer Tanks: Composite Struts
  - Insulation
    - Storage Tank: MLI and SOFI
    - Transfer Tank: MLI
    - Lines, COPVs, Components
  - Pressure Control
    - Storage Tank: Spray Bar and Axial Jet Mixing /TVS Systems
    - Transfer Tank: TVS
  - Active Thermal Control
    - Storage Tank: BAC/Cryocooler system
- LH2 Cryogenic Fluid Acquisition
  - Liquid Acquisition Devices (LADs)
    - Storage Tank: Screen gallery arms with TVS cooling
    - Transfer Tank: Vanes

Flight Representative Capabilities to be Demonstrated on GTA

- LH2 Cryogenic Fluid Transfer
  - Transfer Line Chilldown
  - Tank Pressurization
  - Transfer Tank Chilldown
  - Pressure-fed Transfer
- LH2 Cryogenic Fluid Quantity Gauging
  - Mass Gauging in the Storage Tank
    - RFMG
    - Temperature Rake (Wet/Dry)
    - Cryotracker
    - Capacitance Probe
  - Mass Gauging in the Transfer Tank
    - RFMG
    - Temperature Rake (Wet/Dry)



- Automated Software Sequences
  - Development / demonstration of automated programs

Subset of Manufacturing / Development Activities (In-work / Accomplished)

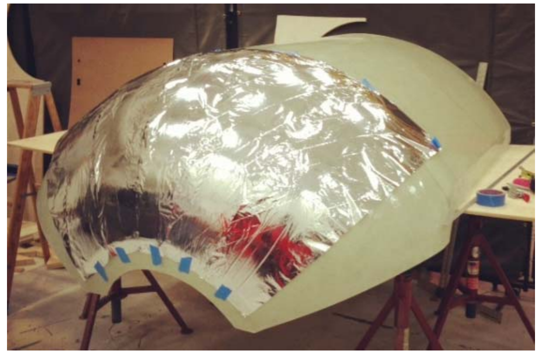
C-Seal Test Set-up

Strut Development

Cryovalve Development

Subset of Manufacturing / Development Activities (In-work / Accomplished)

Pressurant Diffusers



MLI Layup Table

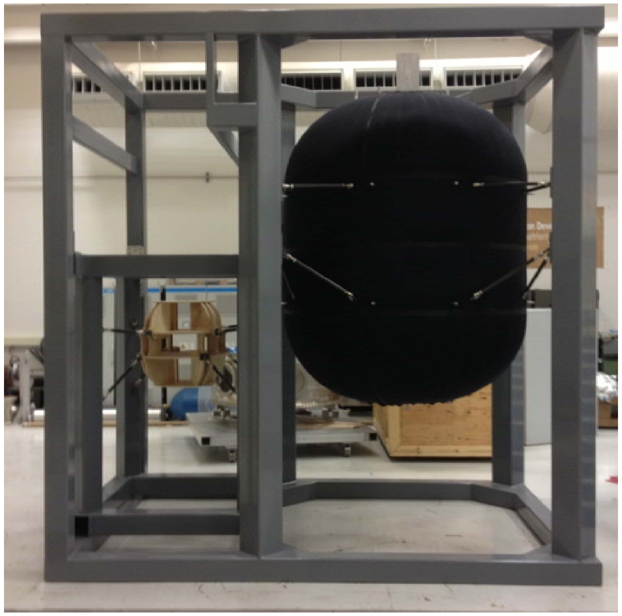
Transfer Tank TVS Tubes

Storage Tank Dome

Storage Tank LADs

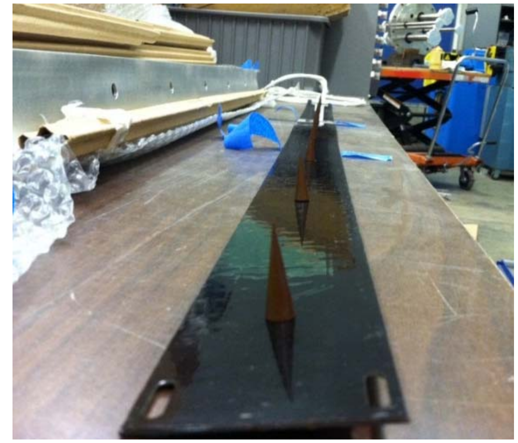
Welding Pathfinder

Subset of Manufacturing / Development Activities (In-work / Accomplished)



GTA Mock-up and MLI Test-Fit Tool

Pressurization Panel Testing



Reduced Gravity CryoTracker

Low Temperature Calibration Set-up

Internal Fluid Line Silicon Diode Mounting

Major Changes since TIM 1

- Conceptual level design matured to implementation design
  - Welding Interfaces
  - LAD design including attachments
- Instrumentation List Defined and Types Selected
- Low Temperature Pressurization Valves Included
- 2^{nd} Pressurization Leg Incorporated for Storage Tank
- Vent Configuration Updated on Storage Tank
- TVS sizing updated
- Removed
  - Burst Disk
  - Transfer Pump
  - Storage Tank and Transfer Line Camera

Major Updates / Increases in Fidelity Since TIM 1

- ~100 Change Packages presented to IDT (subset listed below)

LAD Design	Flowmeter Selection	Overall Design	Tank Acceptance Plan
Instrumentation Feed Thru Selections	Burst Disk Removal	Established Thermal Environment	Updates to TVS Configurations
Removed Transfer Pumps	Defined Heater Requirements	Defined Strut Straps	Removed Storage Tank Camera
Removed Transfer Line Camera	Added External Cameras	Updated Cleanliness Requirements	Defined Redlines & Bluelines
Selected Pressure Transducers	Defined Test Area Operating Response Time	Updated MLI Performance Assumptions	Defined Pressurization and Venting Control Logic
Defined Pressurization Orifices	Updated Pressure Budget	Updated Storage Tank Heat Loads	Updated MLI insulation requirements
Tested C-Seals	Defined Strut thermal barrier	Defined cryovalve performance	Set Test Area Interfaces
TVS Performance	Purge requirements	Refined Schematics	Baselined Instrumentation List

Lessons Learned

- Embracing Lean Engineering Approaches did not always produce savings.
  - Maintaining requirements through use of Change Packages
  - Reduced Dimension Drawings
  - Time and $$ is associated with the learning curve
- Define Success Criteria Earlier
  - Could potentially impact design
  - Can help prioritize analysis
- Define early on path forward for baselining documents that reach outside of the IDT.
- Building up a "flight-similar" integrated CFM system is not easy.
  - Dome thickness non-conformity
  - Dome to barrel weld mismatch non-conformity
  - C-Seals *[Example of a design feature incorporated without sufficient supporting data.]*
  - LADs
  - SOFI / MLI
- Many other features still need evaluation in an integrated system to address flight development gaps and anchor analytical predictions for flight design.

Through lessons and knowledge gained in the development of GTA, the CPST Team is better equipped to address flight challenges.